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Development of a $10/kW Bipolar Plate Separator Plate

by

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Abstract

IGT and its subcontractors Superior Graphite Corporation and Stimsonite Corporation identified moldable blends of graphites, resins, and additives and produced a molded composite graphite bipolar separator plate that is equivalent in function and performance to state-of-the-art machined graphite plates. Complicated flow field designs can be formed with molding. Applications for patents for the blended components have been submitted and PEM Plates, LLC was formed to commercialize the production of the molded graphite bipolar separator plates. Material and production costs for commercial quantities of the plates are targeted for under $10 / kW depending on the complexity of the design of the bipolar plate and fuel cell stack. The molded graphite plates have been tested over the past two years at IGT and at other fuel cell stack developers. Numerous out-of-cell tests measured excellent electrical, chemical, and physical properties. Extensive single cell tests have shown consistent performance in excess of 5000 hours and tests in well-instrumented multiple cell stacks with water-cooling up to 2300 hours showed that in both test modes, the molded plates performed equivalently to state-of-the-art machined graphite plates.

Introduction

The overall objectives of this program funded by DOE (Contract DE-FC02-97EE50477) are to develop a $10/kW manufactured cost molded bipolar separator plate and to advance the technology to commercial production rates. Based on the performance success of the IGT-molded composite graphite bipolar separator plate, PEM Plates, LLC was formed to mold plates for developers worldwide. PEM Plates, LLC is a joint venture of Stimsonite Corporation and ENDESCO Services.

In the first phase of the DOE program completed last year, several resins, graphite types, and additives were evaluated for their fuel cell property enhancement characteristics. Several types of graphite blends were evaluated and the hydrophilic graphite blend selected was a proprietary blend supplied by our subcontractor, Superior Graphite Corp.

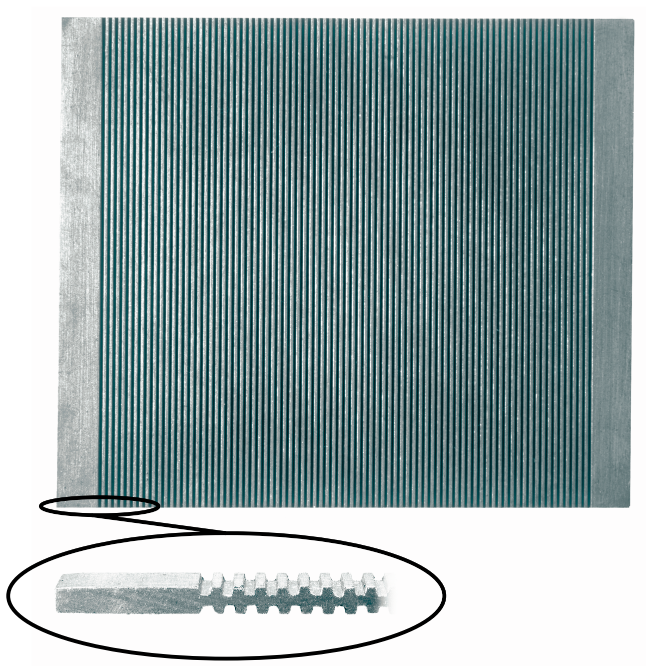

Figure 1. Typical Molded Graphite Plate Flowfield

Bipolar Plate Measured Properties

Dies for IGT bipolar separator plate molds were made with flow fields for an anode and a cathode with water-cooling channels on the opposite side. Measurements of the electrical, chemical, and physical properties of the molded plates have met or exceeded the DOE specified targets as shown in Table 1.

Table 1. Bipolar Plate Properties

Property	**Measured Value**
Conductivity Goal > 100 S/cm	250 – 350 S/cm
Corrosion Goal < 16 $\mu A/cm^2$	< 5 $\mu A/cm^2$
H_2 Permeability	< 2 x10^{-6} cm^3/cm^2-sec (dry, non-porous plates) Bubble pressure > 15 psig (wet, porous plates)
Crush Strength	> 3000 psi
Flexibility	3 – 6% deflection at midspan
Total Creep	~1% @ 200 psi, 100 °C
Material Cost	~ $4 /kW
Manufactured Cost	< $10/kW

The DOE target for conductivity of 100 S/cm measured by ASTM C-661 was typically exceeded by a factor of three. The corrosion rate target of 16 $\mu A/cm^2$ in hydrogen, air, and oxygen atmospheres were performed in an aqueous solution of 2 ppm fluoride using ASTM G5 at 90°C, pH~4. The IGT molded composite blend measured rates below 5 $\mu A/cm^2$. Hydrogen permeability was measured as a function of molding pressure, for either dense, non-porous molded plates or plates molded with some degree of porosity. The hydrogen permeability rate for the dense, non-porous plates was 2 x 10^{-6} cm^3/cm^2-sec at 90°C and 30 psi, well below the specified value of 16 x10^{-6}.

Additionally, IGT measured the strength, flexibility, and creep characteristics of the plates anticipating a magnitude of 200 psi fuel cell holding forces, non-uniformity of gasketing and stack assembly, plus handling and packaging actions from the production line. These values in Table 1 are expected to be within a good safety factor. The plates also have retained their properties after being subjected to immersion in boiling water and freeze-thaw cycles.

Multi-Cell Fuel Cell Stack Performance

In Phase 1 of the DOE program, IGT molded 50 cm^2 and larger 300 cm^2 active area bipolar separator plates for property measurements and also for single cell performance testing. The single fuel cell performance was compared to operation in state-of-the-art machined graphite plates under identical conditions. Performance was nearly identical to the state-of-the-art machined graphite (about 3% lower performance of ~15 mV @ 400 mA/cm^2) mainly due to the slightly higher surface resistance of the presently molded plates as shown in Figure 2.

The performance shown in Figure 2 was very stable over the 2000 hours of testing which was conducted as a continuous 24 hours per day test. In this period, weekly diagnostic and open circuit measurements were made. Following the 50 cm^2 testing, full-size 300 cm^2 active area plates were tested and the same performance and endurance were obtained to confirm the scaleup of the molded graphite plates.

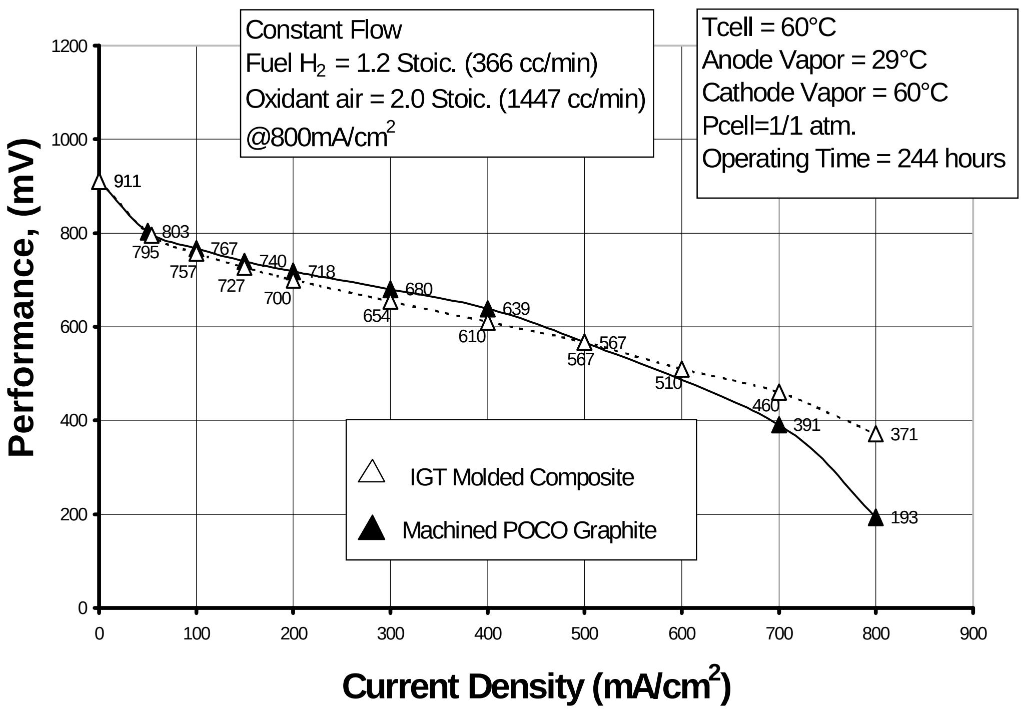

Figure 2. Comparison of IGT Molded Graphite Cell with Machined Graphite

In Phase 2 of the DOE program, the molded graphite plates were evaluated in the environment of short stacks. The single cell tests established excellent molded plate performance, but these operate isothermally. Operation of fuel cell stacks involves non-isothermal conditions, active cooling, proper sealing, type of seals, and clamping forces. All of these functionality issues address the durability of the molded bipolar plate.

Full size anode and water-cooled cathode molded bipolar plates were molded for IGT by PEM Plates. These were assembled and tested at IGT in 4, 7, and 20 cell fuel cell stacks. AlliedSignal will test the molded plates in their design later in 1999.

The operating performance of the 20-cell IGT stack, 1.5kW, is shown in Figure 3 up to 2200 hours of operation. The stack was operated at near ambient pressure and temperature of 60 °C for most of the 2200 hours of operation. Another period to establish endurance at 80 °C is planned.

Cost Studies and Commercial Production

The cost analysis was updated and indicates that the materials used in the molded plate in commercial quantities comes to about $1.46 per pound. Using the DOE power density and active area per kilowatt goals, this cost translates to about $4.10/kW. Manufacturing costs are judged to be within $6/kW, so that the total molded separator plate cost should be under $10/kW depending on the complexity of the design.

The molded separator plate information developed in this work is applicable to most any size and shape of bipolar plates; that is, molding to any final net shape is possible with no finishing steps necessary. However, designs with complicated features may cost more to manufacture.

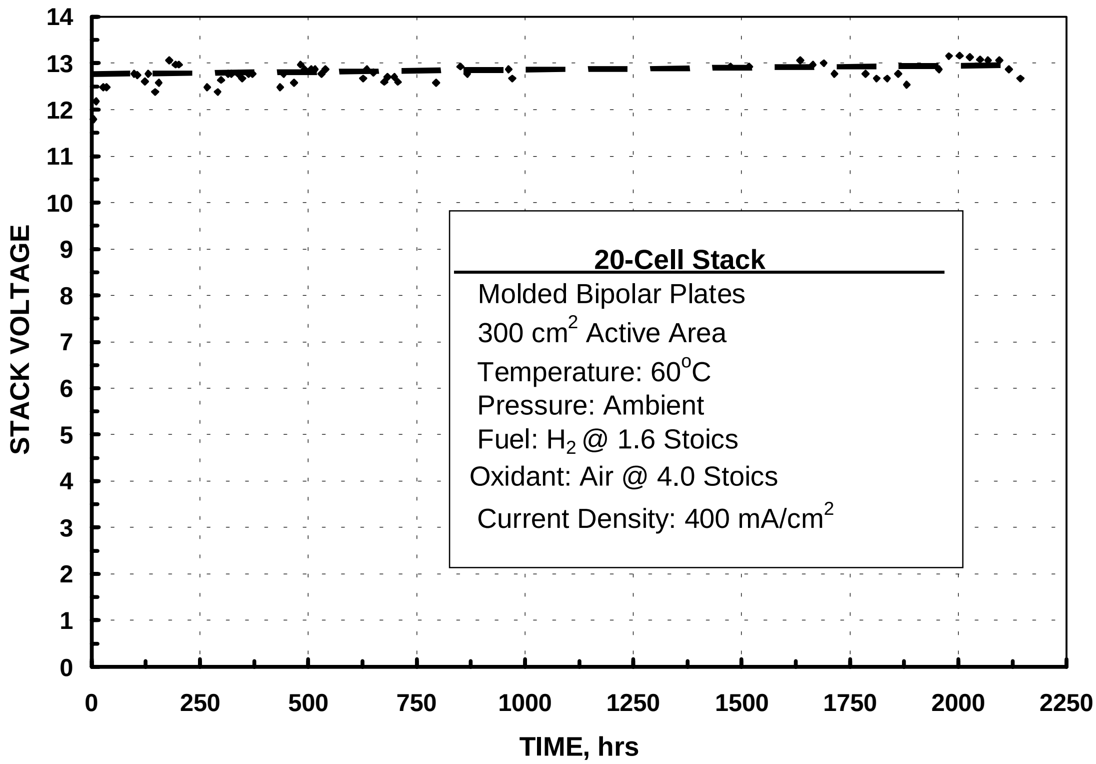

Figure 3. Life Test of IGT 20-Cell Molded Bipolar Plate Fuel Cell Stack

Future Directions

PEM Plates, LLC has built a pilot production line with a molding capacity of 5 plates per hour to evaluate the steps in molding. The pilot line addresses the key automation steps for preparation of the composite blend, transferring to the mold, forming of the plates, releasing from the molds, post-molding operations, and QA/QC operations.

Several fuel cell stack developers have evaluated the quality of the molded graphite bipolar plate, and have requested bipolar plates to be molded. PEM Plates operates on a confidential basis with developers independent of IGT and its subcontractors.